

recognized that a cylindrical graduate tapered at the bottom and having a capacity of 50 drams or more would be convenient; but it would probably not be found in the open market. A detailed description of the gage, with illustrations follows. A model is also available for examination at the Weather Bureau office in Washington.

DESCRIPTION OF FLUID DRAM RAIN-GAGE

The assembled gage is cylindrical, with outside diameter $5\frac{7}{8}$ inches, and over-all height $15\frac{1}{4}$ inches, designed upon the general plan of the Snowdon rain-gage, well known in England, but with dimensions and parts chosen with a view to construction from standard material. The complete instrument consists of the following parts:

1. *The body.*—This is a sheet copper, cylindrical can, 12 inches deep, and with diameter as near to 5.359 inches as is practicable in construction. This can may also be used as a snow gage. Remembering that the probable error in the catch of snow is much greater than in the catch of rain, it will be apparent that if the diameter of the copper can approximates the above value, snow collected in it may, when melted, be measured in the glass graduate.

2. *The funnel collector.*—This is a sheet-copper cylinder 5.6 inches inside diameter by $4\frac{1}{2}$ inches long, with the funnel proper soldered to the sides halfway up. The upper half of the cylinder gives depth to the collector. The lower half telescopes over the gage body for a distance of about 2 inches. The funnel proper is made with a 45° slope to a central outlet formed by soldering in a piece of brass tube $\frac{3}{8}$ -inch inside diameter by 1-inch long to form a discharge spout that terminates about 1 inch below the lower rim of the cylinder. A groove rolled in the cylinder serves to provide a definite stop for the funnel proper, gives additional stiffness to the construction, and forms a stop when the funnel is placed in position on the gage body. To the top of the funnel is soldered a stiff brass ring. This ring is important since it defines the area of collection. Its inside diameter must be turned true to 5.359 inches, with assurance that the actual result is within 0.01 inch of the specified diameter, and from the top the metal must be cut away to produce a slant outward and downward about 60° below the horizontal in a way to form a knife edge to "split the drops of rain." The brass ring is rabbeted out one-eighth inch on its lower inner side to form a recess into which the copper funnel may be soldered. Probably the best procedure is to have a molder make a solid cast brass ring three-fourths inch high by three-eighths inch thick by $5\frac{7}{8}$ inches outside diameter and have a good machinist do the finishing work.

3. *The retaining bottle.*—This is simply a half-gallon commercial glass vinegar jug intended to hold the rain and prevent evaporation until a measurement is made. If it should be broken through freezing or otherwise another may easily be obtained. It centers loosely in the gage body, thus directing the discharge spout from the funnel into the neck of the bottle without special effort.

4. *The graduate or measuring vessel.*—It is best to have a graduate marked in fluid drams because of the greater accuracy attainable. However, the total capacity of a graduate so marked is generally only 16 fluid drams, and hence it is a good plan to have at hand several auxiliary bottles which may be calibrated by pouring into them from the accurate graduate enough water to bring the

height to a point which should be marked in the neck. These calibrated bottles expedite the measurements of heavy rains. Actual trials by different observers have demonstrated that in 16-ounce graduates marked in fluid ounces the necessary eye interpolations between the lines can be made with a reasonable degree of accuracy. Readings are always made by looking horizontally across the lowest part of the curved meniscus of the water surface.

5. *Conversion.*—In a gage constructed as above 1 fluid dram equals 0.01 inch, 1 fluid ounce equals 0.08 inch, 1 pint equals 1.28 inches, 1 quart equals 2.56 inches, one-half gallon equals 5.12 inches. In case of an unusually heavy rain the jug may overflow, but we still have a reserve capacity in the can to care for a total rain of 10 inches.

6. *Cost.*—The cost of a sample gage made according to these specifications was as follows: Copper body and funnel, \$4; brass rim, \$1.78; retaining bottle, \$0.15; 16-dram graduate, \$0.60; total cost, \$6.53; overhead and profit not considered.

7. *Manufacture.*—The best method of construction is to have the entire gage made by a competent manufacturer of meteorological instruments; but where such manufacturers are not accessible the brass ring can be cast by a molder, then turned true by a machinist, then taken to a sheet-metal worker to be built into the gage. This method of construction places upon the owner final responsibility for the accuracy of the collector.

THE CRITERIA OF A COLD WINTER

By ALFRED J. HENRY

The need is often felt of criteria to briefly and precisely express the degree of abnormality of a season, more particularly the winter. Common usage employs the adjectives hard, severe, or mild and open, to distinguish between the two extremes usually experienced. Common usage, however, is notoriously inexact and different persons use the above-mentioned adjectives in a different sense.

The writer has sought to classify winters as a whole, meaning the usually recognized winter months of December, January, and February, according to the abnormalities of temperature which these months exhibit. He has also attempted, although unsuccessfully, to attach weights to the different winters based on the money loss suffered by transportation and agricultural interests as a direct result of adverse weather.

At present there is no organization under Government control through which a census could be made of the economic results of severe winter weather, and, moreover, difficulties arise in the exact delimitation of the areas that suffered economic loss. These and other conditions operate to restrict the useful criteria to those of a meteorological nature.

The chief meteorological criteria must of necessity be temperature and precipitation, of which the latter, in winter, is of secondary importance.

Temperature data may be utilized in several ways, for example, in order to determine the months of greatest cold, the number of days with minimum below an arbitrarily selected figure may be compiled; or, instead of using absolute minima, departures from the monthly means may be used. Any temperature data utilized must be arbitrarily selected with reference to the climate of the region, particularly the degree of continentality that obtains. Numerous trials have been made in order

to determine whether any particular phase of the temperature data is best adapted to indicate the degree of abnormality of the season. As a result of these trials it was found that the order of magnitude of the abnormality was practically the same whatever method was used; hence in the interest of simplicity the method of departures of the monthly means from normal has been selected. This method is, in short, as follows: If the monthly departures of December, January, and February be expressed by $a+b+c$, then the algebraic sum of these departures divided by 3 will give a value that may be considered as expressing with fair accuracy the temperature abnormality of the winter. A concrete illustration follows. Winter of 1924-25 at Washington, D. C., temperature departure of the three winter months, Dec. -0.2 , Jan. -0.4 ; Feb. $+7.8$; sum, $+7.2$, which divided by 3 gives a departure for the winter of plus 2.4 F.

The abnormalities for five stations, San Francisco, Salt Lake City, Denver, St. Louis, and Washington, have been computed for each winter of the record from about 1871 to 1923. The individual seasonal departures may be arranged in a descending series from the coldest winter of record to those that may be classed as average or moderately cold. This has been done, although the table is not reproduced. It shows that extremes of cold weather are rarely, if ever, so widespread as to embrace the greater part of the area of continental United States, but rather the tendency is for the extreme cold to be localized in a relatively small area; hence the table does not answer the question, "What was the coldest winter in the United States as a whole during the last 50-odd years?" The magnitude of the temperature departure depends, of course, upon the continentality of the different parts of the area; for example, the northern boundary States of Montana, North Dakota, and Minnesota, being remote from the oceans and in close contact with regions to the northward having severe winters, show the greatest variations from the monthly means, and the magnitude of these variations diminishes with distance to the south and toward both the Atlantic and Pacific Oceans. There is, moreover, a tendency toward a reversal of the sense of the temperature departure between the Pacific slope States and the region east of the Rocky Mountains. The second coldest winter at San Francisco, 1889-90, was the warmest winter in the 50-odd years east of the Mississippi. There is also some indication of a west-to-east movement of great abnormalities, as, for example, the coldest winter at Salt Lake City, 1916-17, was followed by the very cold winter of 1917-18 east of the Mississippi. Other interesting comparisons are possible. The abnormalities of individual seasons for, say, 50 years also afford some basis of classification. Two tentative classifications, the first for the Pacific coast, the second for the interior, are presented below.

Classification of winters

	(a) Pacific	(b) Interior
Average winter, limits between.....	+0.5 and -0.5	+1.0 and -1.0
Moderately warm.....	+0.6 and +1.5.....	+1.1 and +3.0.....
Warm.....	+1.6 and +2.5.....	+3.1 and +5.0.....
Very warm.....	+2.6 up.....	+5.1 up.....
Moderately cold, limits between.....	-0.5 and -1.5	-1.1 and -3.0
Cold.....	-1.6 and -2.5	-3.1 and -5.0
Very cold.....	-2.6 up.....	-5.1 up.....

An example of the classification of winters according to the limits above given is given in Table 1.

TABLE 1.—*Abnormal winters at San Francisco, Salt Lake City, Denver, St. Louis, and Washington, classed as average, moderately cold, cold, very cold, etc.*

	San Francisco		Salt Lake City		Denver		St. Louis		Washington	
	Years	Departures	Years	Departures	Years	Departures	Years	Departures	Years	Departures
Average.....	1891-92	± 0.0	1919-20	-0.7	1879-80	-0.8	1914-15	-1.0	1882-83	-0.8
Moderately cold.....	1897-98	-1.2	1887-88	-1.5	1876-77	-2.7	1919-20	-3.0	1884-85	-2.6
Cold.....	1882-83	-1.7	1892-93	-3.7	1878-79	-4.0	1901-02	-4.3	1892-93	-3.5
Very cold.....	1909-10	-2.5	1916-17	-5.8	1898-99	-7.3	1917-18	-6.9	1904-05	-5.5
Moderately warm.....	1888-89	+1.3	1899-00	+1.4	1889-90	+2.3	1891-92	+2.3	1895-96	+1.8
Warm.....	1917-18	+1.8	1920-21	+3.1	1895-96	+4.5	1918-19	+5.2	1890-91	+3.2
Very warm.....	1876-77	+3.2	1906-07	+5.7	1906-07	+5.8	1889-90	+9.1	1889-90	+9.8

A REMARKABLE TWO-THEODOLITE PILOT-BALLOON SERIES

By WILLIAM C. HAINES

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An interesting series of two-theodolite pilot-balloon observations was made at the aerological station at Broken Arrow, Okla., on October 14, 1924. The series consists of five soundings, all of which reached altitudes of 11,000 to 14,000 meters (roughly 7 to 9 miles) above the surface. Wind velocity and direction graphs of four of the five soundings are reproduced in Figure 1. The observations were made at 7:03a, 10:05a, 1:23p, 3:02p, and 4:57p. The graph of the observation taken at 4:57p, is omitted from the accompanying figure, but it is similar to the other four in all essential characteristics. Since all of these observations were made with two theodolites, their accuracy can not be questioned.

The following are some of the interesting features of the observations: Light winds averaging only 4 or 5 meters per second (about 10 miles per hour) prevailed up to approximately 7,000 meters. Above this altitude the wind increased very rapidly, attaining velocities as great as 50 meters per second (112 miles per hour). Apparently above 13,000 meters the velocity decreased as shown by the highest graph. The wind direction above 4,000 or 5,000 meters was from west to northwest and remained practically constant throughout the day. Below this altitude the direction was variable, finally shifting to southeast from the surface up to 3,000 meters in the late afternoon.

Another interesting feature of the series is the persistency throughout the day of the small irregularities in wind velocity. Note the increases in velocity marked "a" and "b," which are evident in all four graphs. They are also just as pronounced in the fifth graph, which is not reproduced.

The weather map on the morning of the 14th showed a flat HIGH central over the upper Mississippi Valley, with a weak trough of low pressure extending north and south across the country just east of the Rocky Mountains. The high-pressure area moved eastward and at 8 p. m. was central over the Upper Lake region.

It is probable that all of these soundings penetrated the stratosphere, although there is nothing to bear out this statement except the height attained and the decrease in velocity above 13,000 meters. High velocities are not always present at great altitudes. Many soundings that reach altitudes from 10,000 to 15,000 meters show comparatively low wind velocities from the surface up. Very often the wind velocity at high levels appears to bear no relation to the surface condition shown by the current weather map.